

Additionality of Public R&D Grants in a Transition Economy: the Case of Eastern Germany

Dirk Czarnitzki* and Georg Licht**¹

* Catholic University of Leuven (KUL), Leuven, and ZEW, Mannheim

** Centre for European Economic Research (ZEW), Mannheim

March 2005

Abstract

This paper examines the input and output additionality of public R&D subsidies in Western and Eastern Germany. We estimate the impact of public R&D grants on firms' R&D and innovation input. Based on the results of this first step we compare the impact of publicly funded private R&D on innovation output with the output effect of R&D funded out of firms' own pockets. We employ microeconomic evaluation methods using firm-level data derived from the Mannheim Innovation Panel. Our results point toward a large degree of additionality in public R&D grants with regard to innovation input measured as R&D expenditures and innovation expenditures, as well as with regard to innovation output measured by patent applications. Input additionality has been more pronounced in Eastern Germany during the transition period than in Western Germany. However, R&D productivity is still larger for the established Western German innovation system than for Eastern Germany. Hence, a regional redistribution of public R&D subsidies might improve the overall innovation output of the German economy.

Keywords: R&D, innovation, subsidies, evaluation of public policy

JEL-Classification: C14, C25, H50, O38

Contact: Dirk Czarnitzki
KU Leuven
Dept. of Applied Economics and
Steunpunt O&O Statistieken
Dekenstraat 2
3000 Leuven
Belgium
Phone: +32/16/325727
E-mail: dirk.czarnitzki@econ.kuleuven.ac.be

Georg Licht
Centre for European Economic Research (ZEW)
Industrial Economics and International
Management
P.O. Box 10 34 43
68034 Mannheim
Germany
+49/621/1235-177
licht@zew.de

¹ We are indebted to Creditreform for supporting us with credit rating data, to Günther Ebling, Norbert Janz, Bettina Peters and Sandra Gottschalk for careful preparation of the innovation survey data and Thorsten Doherr for augmenting the Innovation Survey data with information on patent applications at the firm level. Significant parts of the paper were written during Dirk Czarnitzki's stay at the University of California at Berkeley. We thank the Volkswagen Stiftung for financial support as well as Bronwyn H. Hall and Guido W. Imbens for their hospitality and advice.

1. Introduction

Over the last couple of years the catching-up process of the former East Germany has not lived up to its expected speed. Labour productivity is still significantly lower in Eastern Germany than in Western Germany: unemployment is much higher and the value of regional production falls short of regional consumption (cf., e.g., Burda and Hunt 2001). Hence, based on the convergence speed realised in the first phase of the catching-up process, a significant transfer of income will be needed for a much longer time period than expected. Neither the private nor the public sector in Eastern Germany will be viable without a massive influx from the western parts of Germany.

In 2004, various critical reviews of the current means of stimulating the catching-up process have been published, inducing a wide-ranging discussion on how to foster the transition of the former East German regions. The German federal government's 2004 (Bundesregierung 2004) report on the "status of German unification" suggests a rapid expansion in manufacturing. According to the government's view, the stagnant catch-up process has been primarily caused by the downturn of the business cycle in the last three years. However, the report also suggests a revision of current policy instruments. Based on an appraisal, the current situation and the perspectives for Eastern Germany, the federal government's high-level expert group also called for major revisions of policy approaches (cf. Seitz 2004, Dohnani 2004). This group also raised the question of whether the low growth rates of the western regions in the last ten years was caused by the huge 4% regional product burden implied by the financing of transfers to the eastern regions.

The emerging general consensus in economic policy holds that transfers should focus on investments in innovation, research and development. Likewise industry associations as well as many firms suggest additional public intervention, lamenting their limited financial resources and severe barriers to acquiring bank loans. Without additional public subsidies for investment, innovation and R&D, the private sector in Eastern Germany will not be able to profit from EU enlargement. Caught between highly productive western European industries and low-wage industries in the new member states, Eastern German firms face a dilemma and rapid productivity gains induced by increased investments in physical and knowledge (R&D) capital seem to be the only way out. However, public subsidies for those types of private investments have been at record levels in Eastern Germany for more than a decade now and many doubt the effectiveness and efficiency of even larger subsidies (e.g. DIW/IAB/IfW/IWH/ZEW 2003).

Against this background this paper examines the effectiveness and efficiency of public R&D grants for private sector R&D projects. We restrict our analysis to programmes which involve a direct payment to private firms. However, we do not intend to evaluate single programmes, looking instead at the "average" impact of public R&D subsidies on private R&D. In addition, we examine both sides of the link between R&D - publicly funded and funded by firms from their own pockets - and innovation output. We use the relation between publicly funded R&D and innovation input and output in Western

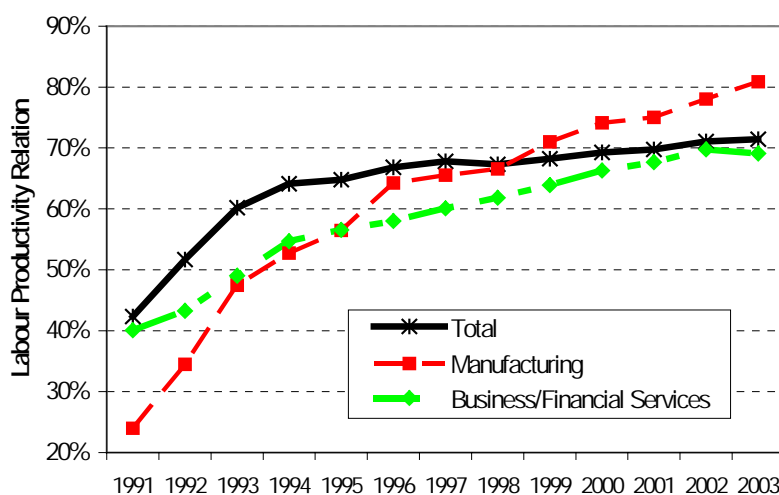
Germany as a benchmark for the impacts of R&D programme during the first ten years of the transition process in Eastern Germany.

In Section 2 we introduce some basic facts about innovation and productivity growth in Eastern Germany. In addition, we highlight some evidence of the credit market squeeze felt by firms from Eastern Germany using Western Germany as a benchmark. Section 3 shortly introduces the method used to examine the effectiveness and efficiency of public R&D subsidies, and Section 4 describes the data used. In Section 5 we look at the impact of public R&D subsidies on private R&D and discuss reasons for the divergences between Eastern Germany and Western Germany. Section 6 deals with the impact of public subsidies on innovation output. Again, we highlight differences with regard to the impact of R&D subsidies in both parts of Germany. We use the well-known concept of the knowledge production function to derive measures for the efficiency of public subsidies concerning innovation output. Finally, Section 7 summarises the results. In addition, taking the current policy discussion as a standard, we discuss some implications of our econometric results.

2. Innovation activities and R&D during the German transition

Since the fall of the Berlin Wall in 1989, Eastern Germany has drastically reduced the huge initial productivity gap. Figure 1 demonstrates the development of the relative labour productivity level in Eastern Germany for the total economy and manufacturing and business services. The figure shows the Eastern German economy's initially rapid productivity recovery.

Figure 1: Productivity level comparison of Eastern Germany relative to Western Germany (Western Germany = 100%)



Annotation: Eastern Germany comprises the new *Länder* (states) excluding Berlin. Berlin is also omitted from the Western German data, because a separation of East Berlin and West Berlin is not possible. Labour productivity is calculated as value-added in constant prices divided by number of employees.

Source: *Statistische Ämter der Länder* (state statistical offices) (2005), *Volkswirtschaftliche Gesamtrechnungen der Länder* (national accounts), Series 1, Volume 1.

At the macro-level (“total economy”), a drastic slowdown in the speed of convergence is visible in 1995/1996. This deceleration is less pronounced in manufacturing as well as in the business service and financial service sectors. The difference in development between the overall economy on the one hand and manufacturing and business services on the other reflects the waning of the construction industry-based growth seen in Eastern Germany in the first phase of the transition process.

The continued productivity recovery of Eastern German manufacturing has been fuelled by extensive investment in new equipment, which has in turn been stimulated by generous government subsidies. (cf. Hunt and Burda 2001). Thus, the catch-up process in manufacturing has been mainly driven by increasing the stock of physical capital. Physical investment per employee and investment per unit of output has at times been much higher in Eastern Germany than in Western Germany. In addition, an extensive transfer of know-how and organisational innovation has taken place via the direct investments of Western German and foreign companies (see Burda and Hunt 2001).

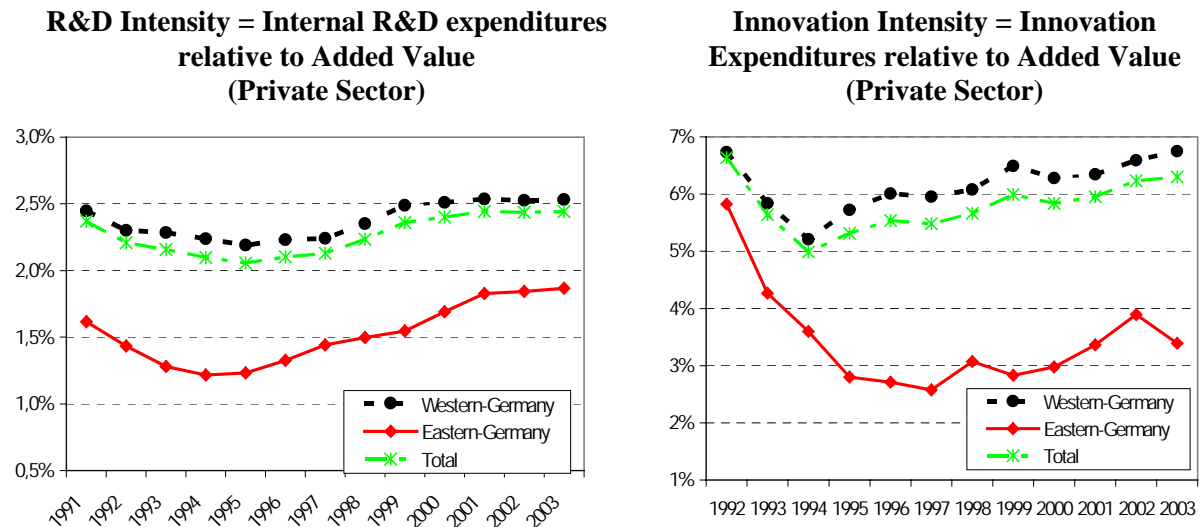
The catching-up process is also visible with respect to the international competitiveness of Eastern German firms. The East's increasing export ratios even outperformed the success of Western German firms in international markets. The compound growth rate of exports in the period from 1996 to 2002 amounted to 21% p.a. R&D-intensive industries took the lead with a 26% annual growth rate in exports. This contributed to a significant 12% growth p.a. in R&D-intensive industries. However, there is still a significant gap in export ratios compared to Western Germany. The exports to total sales ratio amounts to 41% in Eastern Germany, whereas the ratio for Western German R&D-intensive manufacturing approaches 55%. (cf. Legler et al. 2004 for details).

The reorganisation of the Eastern German economy was paralleled by an even stronger reorganisation of the (regional) innovation system (see Meske 2000, Leydesdorff and Fritsch 2005). Just after unification the number of industry R&D personnel dropped considerably. Still today, innovation expenditures as well as R&D expenditures are much lower in Eastern Germany than in Western Germany at the aggregated level. This is depicted in Figure 2.

Both R&D and innovation intensity² declined during the first transition phase, mainly due to the rapidly rising added value but also due to the decreasing degree of R&D employment in manufacturing witnessed up until 1993. Since the mid-1990s, R&D and innovation intensities have increased and the significant gap between Eastern and Western Germany has only gradually reduced. This is notable because the growth rates in manufacturing and business services, which contribute to the bulk of R&D and innovation expenses, are larger in Eastern Germany than in Western Germany, implying an even larger growth rate of R&D and innovation expenses.

² Innovation expenditure are defined following the OECD Oslo Manual. Innovation expenditures comprise R&D expenditures and other expenditures directly related to the generation and implementation of new and improved products and processes, e.g., costs of new production processes, employee training expenses, and/or costs incurred acquiring IP rights (see OECD and Eurostat 1997 for details).

Figure 2: R&D intensity and innovation intensity of the private sector in Eastern and Western Germany



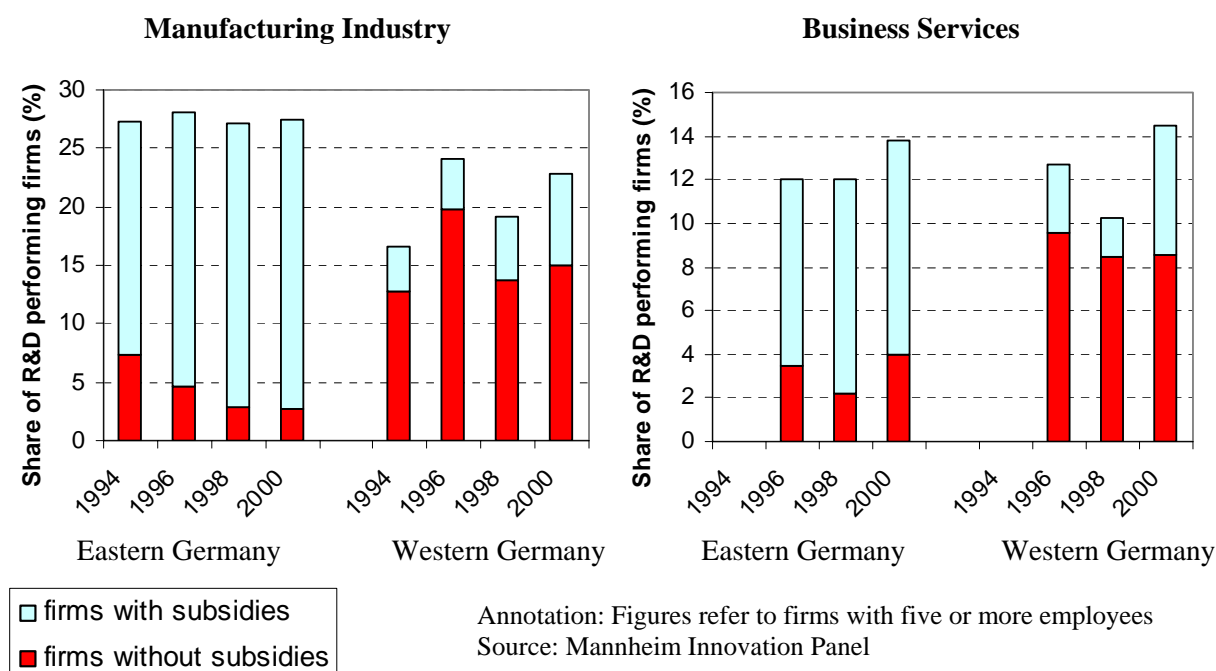
Source: Stifterverband; VGR der Länder
Annotations: Eastern Germany includes Berlin

Source: ZEW, VGR der Länder
Annotations: Eastern Germany includes Berlin; 1993-1996 are partly estimated

Fostering the competitiveness of Eastern German firms by stimulating R&D and innovation was a prime goal of the government's economic policy right from the start of the transition period. Various programmes to stimulate private R&D were launched, driven by the conviction that Eastern German firms would only survive in the market place if they were able to improve their technological competitiveness. The weak technological base is still a common economic rationale for such programmes. Another widespread sentiment is that the continual presence of credit squeeze hampers investments in R&D. The numbers in Figure 2 support this widely held belief. However, it is well known that R&D and innovation intensities vary considerably by firm size and industry. Taking the structural features of the Eastern German economy into account, Legler et al. (2004) show that the “adjusted” R&D intensity of the manufacturing sector in Eastern Germany is even higher than that of Western Germany.

Data from the German innovation survey show that the share of manufacturing firms engaged in R&D compared to all manufacturing firms is larger in Eastern Germany. 27% of Eastern German firms performed R&D, whereas this share amounts only to 23% in Western Germany. As shown in Figure 3 the majority of R&D performers in Eastern Germany receive R&D subsidies, while only 30% of R&D performers in the West take part in government-sponsored R&D programmes.

Figure 3: Share of firms performing continuous R&D with and without public R&D subsidies



In addition, R&D intensity (measured as the share of R&D workers in total employment) in R&D performing firms in manufacturing and business services is larger in Eastern Germany than in Western Germany. Given this number, one immediately supposes that the high R&D intensity and the widespread R&D participation of firms are due to the generous R&D support provided to Eastern German firms. However, there seem to be some problems with regard to the efficiency of this huge R&D investment. Legler et al. (2004) give some descriptive evidence showing that the ratio of new product sales to innovation expenditures as well as patents to R&D spending are significantly smaller for Eastern German manufacturing than for that of Western Germany. Against this background, the present paper attempts more formal tests of the lower efficiency of R&D and innovation expenditures in Eastern Germany. It adopts a double-testing strategy. We first look at the relationship between publicly and privately funded R&D in manufacturing, and then compare the gradient of public innovation support on innovation output in both regions.

3. Methodological Approach

The common objective of public R&D support is to increase the size and number of R&D projects performed by private-sector firms. This is especially true for the present R&D support system in Germany which mainly comes as grants to specific projects. Tax credit-based R&D support is not available. Theoretically, public support focuses on projects whose private cost-benefit ratios are small

and will hence only be undertaken if public subsidies are available.³ In order to keep allocation failure at a minimum, the government will only cover a share of the total project cost (typically 50%). As a consequence, public support is expected to induce additional private R&D investment because, due to lower private costs, the private cost-benefit calculation exceeds the threshold value. This implies that the project selection (by the government as well as by the firms) is far from random. Both the government and firms are interested in conducting the best projects. However, firms maximise private value, whereas the government is interested in maximising social value. Hence, a comparison of sponsored and non-sponsored projects will not give a reliable indication of the impact of R&D subsidies, particularly when we leave the project level and look at the firm level: Firms have an incentive to re-allocate resources to R&D-related areas when public support is more likely. Looking at firm-level R&D thus presents a stronger test of the (input) additionality of public R&D support than the project level. Furthermore, firm-level tests of output additionality also take into account negative impacts on R&D productivity resulting from the re-routing effect.

If we observe systematic differences between supported firms and non-supported firms, a pure comparison of the mean impact of the subsidies may lead to biased results. A relevant question to ask would be, for instance, “What is the amount of R&D the company would have spent without subsidies?” The problem is that this situation – the counterfactual – is not directly observable. Hence, in order to make a reliable guess regarding the programme's impact we have to look for methods which facilitate the best possible inference of the counterfactual situation. In the 1980s several econometric models were developed to estimate the counterfactual situation and thus estimate the “treatment effect” in the case of a non-random selection of the group of treated firms.⁴ For this analysis we chose the matching estimator shortly illustrated in the following:

Step 1: Impact of R&D subsidies on R&D input

Our starting point is a question linking the target variable (Y) (e.g., private R&D investment) to the policy instrument and a variety of other exogenous factors (X) which also influence the target variable (e.g., firm size, industry, region, human capital):

$$(1) \quad \begin{aligned} Y_i &= g^1(X_i) + D_i\alpha + u_i, & \text{if } D_i &= 1 \\ Y_i &= g^0(X_i) + u_i, & \text{if } D_i &= 0 \end{aligned}$$

As usual, u_i represents a random variable. The impact of the respective policy instrument is measured by α . D is a simple dummy variable which takes the value 1 if the firm is treated and 0 otherwise. When employing matching estimators, there is no need to make assumptions about the functional form of g^0 and g^1 . This is a crucial advantage of the matching approach.

³ In order to clarify our argument we neglect from capital market imperfections as a rationale for public subsidies (see Hall 2002). See David et al. (2000) or Klette et al. (2000) for recent surveys on the evaluation of R&D policies.

⁴ See Heckman et al. (1999), Blundell and Costa Dias (2000, 2002) for surveys.

The basic idea of the matching approach is to imitate a “natural” experiment where the treatment is randomly distributed between groups of identical twins. Hence, the goal of the matching approach is to find for each treated firm (firms that receive public R&D subsidies) an “identical” non-treated firm. In this case, “identity” means that the firms in each pair have sufficiently similar values with regard to all of the variables summarised in X . Ideally, X contains all of the factors (variables) responsible for participation in public R&D programmes. Depending on the complexity of the decision process, perfect “twins” may be hard to find. Rosenbaum and Rubin (1983) developed an approach to solve the “curse of dimensionality” in the twinning problem: the “propensity score matching”. Instead of using all of the variables contained in X , we can use the estimated likelihood of programme participation conditioned on X . The probability of participation P is modelled as a function of X . The twinning process groups firms with a similar estimated probability of programme participation (“nearest neighbour”). The propensity score is estimated by a probit regression. Based on Rubin’s (1977) conditional independence assumption, the counterfactuals for the treated firms can be subsequently estimated by the values of their nearest neighbours:

$$(2) \quad E(Y^0 | P = X\hat{\beta}, D = 1) = E(Y^0 | P = X\hat{\beta}, D = 0),$$

where $\hat{\beta}$ represents the estimated coefficients of the probit model for programme participation. Based on the estimated propensity score we find the “nearest neighbour” using the following procedure:

1. Let $\{(1)\}$ represent the treated firms, $\{(0)\}$ the non-treated firms
2. Randomly select a firm i from $\{(1)\}$.
3. Find another firm $j \in \{(0)\}$ which is closest to i in terms of its propensity score P .
4. Select firm j as a twin to i .
5. Repeat steps 2 to 4 for all firms in $\{(1)\}$.

When this process is finished the average impact of the programme on the treated (Average Treatment Effect on the Treated "ATT") is calculated by

$$(3) \quad \alpha_{ATT} = \frac{1}{N^1} \sum_{i=1}^{N^1} (Y_i^1 - \hat{Y}_i^0),$$

N^1 represents the number of treated firms. In addition to the standard propensity score matching, we assume that the firms are identical in a certain number of characteristics. We also stipulate that twins stem from the same industry.

In the empirical analysis we use different measures of innovation input in order to increase the robustness of our conclusions. Given the availability of the innovation survey data, we first explore the impact of public R&D subsidies on R&D input. Secondly, we use the concept of innovation

expenditures, which comprises R&D and other inputs needed to bring new products to the market and/or use advanced production equipment.⁵

Step 2: Impact of R&D subsidies and privately funded R&D on innovation output

The second step of our analysis attempts to ascertain whether there are productivity differences between government-funded R&D and R&D funded out of firms' own pockets. This allows some insight into questions of efficiency with regard to public R&D funding. The point of departure is a typical Griliches invention production function linking innovation output to innovation input.

We assume that the innovation output of firm i (O_i) is a function of R&D input and a vector of the control variable Z . The novel aspect of our approach is its separation of R&D expenditures into two components. In Y_i^0 and $\alpha_i = Y_i^1 - Y_i^0$ that is, in R&D that would have been carried out regardless of public R&D subsidies (Y_i^0) and in R&D expenditures induced by public funding ($Y_i^1 - Y_i^0$). The values for Y_i^0 and α_i were calculated as a result of the matching approach. Hence:

$$(4) \quad O_i = f(Y_i^0, \alpha_i, Z_i)$$

Comparing regression results found for Y_i^0 and α provides some hints of whether there might be differentials with regard to the productivity of both types of R&D. We restrict the second step to patent applications as a measure for innovation output because patent applications are in close temporal proximity to innovation input. Other innovation output indicators, e.g., share of sales with innovative products and cost reductions due to new processes, are not employed here because it usually takes some time until the impact of innovation materializes in such measures. As a consequence, however, we may underestimate the impact of re-routing budgets.

4. Data and Operationalisation

The data used in the analysis were taken from the Mannheim Innovation Panel (MIP)⁶, which has been collected by the ZEW via mail survey since 1993. The survey encompasses data on R&D- and innovation expenditures, a wide array of firm characteristics (e.g., firm age, industry, turnover, number of employees, exports, firm integration, market structure) and information on whether or not the respondent firms have received innovation support from public sources (e.g., the EU, the German federal government, their respective state governments, public banks).

This pool of data is supplemented by information from the German Patent Office on each individual firm's patent applications. Depending on the information of public subsidies, four waves of the MIP were used for this study, corresponding to the years 1994, 1996, 1998 and 2000. In the following, the indicators and values for the endogenous variables (publicly sponsored promotion, R&D and

⁵ Innovation expenditures were used already by Czarnitzki (2001); R&D was used by Almus and Czarnitzki (2003) in a similar context.

⁶ Janz et al. (2001) provide a detailed description of this database.

innovation activities, and patent applications) as well as the exogenous variables are introduced. Basic descriptive statistics on sample firms from Western and Eastern Germany and publicly supported and non-supported firms can be found in Tables A1 to A4 in the appendix. In addition to definitions, this section also cites economic rationale for the use of this set of endogenous variables

Public promotion of R&D

A central variable of this study is the firm support status indicator (*PF*), which takes the value 1 if the firm in question received public research support either from the EU, the German federal government or a German state in the observed year.

Expenditures for R&D and innovation

A firm's total R&D expenditures are part of its innovation expenses regardless of their categorization as internal or external. In addition to these expenditures, a logarithm of R&D expenditures is applied as a dependent variable in order to compensate for the skewness in the distribution of R&D ($\ln R\&D$). Moreover, R&D intensity is analysed as $R\&D / SALES * 100$. "Innovation expenditures" include (in addition to R&D expenses) all continuous expenses, such as personnel and material expenditures linked to innovation projects, as well as investments made in the development and introduction of new and improved products and/or processes (cf. Eurostat and OECD, 1997). Innovation expenditures thus contain R&D expenses as well as spending related to prototypes, product design, investment in the manufacture of new and improved products, introduction of process innovations, market launch costs, license acquisition and patent application expenditures, and further education of employees assigned to innovation projects and similar expenses. The innovation expenditure logarithm ($\ln IE$) and innovation intensity ($IE/SALES * 100$) are also used.

Number of patent applications and propensity to patent

Patents are a common measure of innovation output (cf. Griliches 1990 for a survey). The most important advantages of this indicator are its ready availability and comparatively high standardization. Additionally, a patent application is temporally closely associated with the R&D process and hence poses fewer assignment problems between R&D input and output than alternative indicators. The main disadvantage of using patent applications lies in the fact that many patents have only a negligible economic value. Typically, the value of patents varies dramatically (cf. Hall 2000 and Hall et al., 2005 for overviews); not all companies patent their inventions, relying instead on other mechanisms to protect their intellectual property (e.g., non-disclosure). Despite this caveat, this study uses two patent-based measures. The dummy variable $DPAT_{it}$ indicates whether a firm applied for at least one patent in a given year, taking the value 1 if so and zero otherwise. The second measure used is number of annual patent applications PAT_{it} .

Firm size

Increased R&D promotion in the former East German states is in many cases justified by citing the small-business structure of the firms implementing R&D. The related literature presents diverse

discussions on the correlation between firm size and R&D or innovation activities. Arguments in favour of the theory that larger firms are more eager to innovate are also manifold (cf. Cohen 1995 for an overview), extending from improved capital market access and economies of scale and scope to complementarities in implementing innovation marketing. Firm size is considered in terms of number of employees (*EMP*) and is used in logarithmic form ($\ln EMP$). Additionally, $(\ln EMP)^2$ is used to capture possible non-log-linear functional forms.

Herfindahl index of firm concentration

Market structure is traditionally regarded in industrial economic studies as an important determinant of innovation activity. As a rule, one would expect higher profits in highly concentrated markets. The likelihood of state support may also be increased, since fewer companies compete for available resources. Market concentration is measured by the Herfindahl index for turnover at a three-digit industry level corresponding to the NACE classification ($\ln HHI$).

Firm age

Firm age is introduced to capture specific funds available to young firms and these firms' particular needs. As a rule, one refers to young firms' poor access to the capital market and lack of their own financial capacity. Firm age is thus a potentially essential determinant of innovation activity, but also of the probability of participation in public support programmes. The firm age (in years) in logs ($\ln AGE$) is applied in the regressions.

Export activity

One can assume that firms committed to being internationally competitive have a higher propensity to innovate than others. It is also accepted that expansion of innovation expenditures has mainly occurred in more export-oriented branches in recent years. In response, firms' export activity is measured in the estimations using a dummy variable $DEXP_{it}$, which takes the value 1 when exports were recorded for the respective firm and zero otherwise.

Patent stock (previously accumulated patents)

Patent stock approximates firms' past innovation activity and depicts both previously collected knowledge and otherwise disregarded qualities of innovation. The variable *patent stock* (PS_{it}) corresponds to firm i 's number of patent applications (PA_{it}) in year t and patent stock in the previous year $t-1$, the latter of which is inserted into the patent stock calculation in year t with an "depreciation factor" of 15 percent. This deduction accounts for loss and economic obsolescence of knowledge⁷:

$$PS_{it} = 0.85 * PS_{it-1} + PA_{it}$$

The patent information utilized is taken from the DPMA (German Patent and Trademark Office) database and contains data from 1980 on. Patent stocks (PS) are calculated for each individual firm

⁷ Cf. Griliches and Mairesse (1984) or Hall (1990) for further details.

and are then linked to the MIP firm data. For the year 1979 all firms' *PS* values are set to zero. Depreciating the knowledge stocks over time guarantees that the distortion caused by the initial condition of zero is negligible in the period under review. In the regression analyses the patent stock enters with a one-year lag, thereby avoiding endogeneity. This variable is also measured in logs. In cases where the patent stock is zero it is replaced by the smallest positive value observed in the sample. In order to compensate for the resulting distortion, an additional dummy variable *NoPAT* is introduced, indicating zero patents.

R&D department

An experienced work force, accumulated knowledge and modern capital equipment are important factors in carrying out innovation projects. Established organisational structures simplify the bureaucratic investment typically implied by such ventures. Furthermore, one can also suppose that R&D facilities promote participation in government programmes because of superior information about government programmes. R&D departments are natural contact points for scientific institutions looking for partners for collaborative research projects funded by the government. In applying for R&D support R&D facilities can fall back on readily available experience, allowing R&D employees to handle the application with relatively little effort. A dummy variable (*RDDEPT_{it}*) indicates whether a firm has its own R&D department.

Credit rating / access to the capital market

As data from innovation surveys show, high costs of innovation, the significant economic risks involved and a lack of sources of financing rank are among the dominant obstacles to innovation. Lack of financial resources is considered an “innovation barrier” by medium-sized industrial firms in particular. A number of studies (cf., e.g., Toivanen/Niinnen, 2000, Czarnitzki, 2002) provide evidence that restrictions on credit financing of research and development have an immediate effect on firms' R&D intensity. In order to verify capital market restrictions, the CREDITREFORM credit rating index (CR) – used by suppliers, banks, insurance companies, etc., in determining risks involved with clients – is employed. This index can take values between 100 and 600 risk points. The higher the credit rating index, the greater the risk. Firms with up to 130 risk points exhibit an excellent rating, while values of 500 and above strongly suggest avoiding any business relationship.

Firm ownership

Holemans and Sleuwaegen (1988) and Janssens and Suetens (2001) point out that technology transfers within company groups represent crucial determinants of the individual member-firms' respective R&D activities. The corresponding literature offers descriptions of widely varying effect channels and –mechanisms displaying no uniformity with respect to the direction of that effect. The innovation efficiency of Eastern German firms in particular may indeed benefit from membership in such associations (cf. Czarnitzki, 2005). Along these lines, two dummy variables are applied: a binary variable, taking the value 1 when the firm in question belongs to a Western German firm association (*WGROUPE_{it}*), and another which takes the value 1 when the parent company of the firm in question is

based abroad ($FOREIGN_{it}$). In addition, one should bear in mind that these variables also portray access restraints to public research support. Small firms, for example, do not qualify for support programmes meant to encourage SMEs if they are majority-owned by large firms.

Specific industry- and year effects

Additionally, we capture industry-specific impacts and year-specific effects by including industry and time dummies in all of the regressions. Porter (1998), for example, identifies with his diamond-scheme the components market conditions, demand conditions, related and auxiliary industries and firm strategies as the four main determinants of a nation's competitive advantage. Industry particularities not covered by the other variables are hence accounted for with sector dummies. Changes in the general macroeconomic framework can also have an effect on firms' innovation activity. For instance, a recession can present challenges to parties seeking sufficient capital for R&D projects; changes in the capital market can lead to postponements in firms' investment opportunities as they readjust their resource allocations. In order to control for these and many other possible temporal influences in the regressions, four year dummies are included in all the analyses.

5. Impact of Public R&D Subsidies on Innovation Input

A number of scenarios arise in the empirical analysis. As Czarnitzki (2002) describes, the existence of government funding can engender two different reactions. When such promotion has a stimulating effect on innovation input, one wonders what course the affected firms would have taken had they not received any assistance. On the one hand, the firms' levels of R&D expenditures, for example, might have been lower without support. On the other hand, however, small and medium-sized companies in particular may not have been able to engage in any R&D at all without government subsidies. Eastern German firms would have also abandoned R&D efforts after encountering capital market restrictions. These considerations give rise to two options:

- The initial estimation contains in the potential control group all non-supported firms, regardless of whether they are engaged in R&D or not; this will allow for firms changing their R&D status.
- In the second estimation the control group is limited to firms permanently conducting R&D. This likely underestimates the effect of promotion, as it is assumed implicitly that R&D promotion alone is not able to motivate firms to start R&D activities.

Case I: Government-funded R&D performers vs. all other firms

Programme participation and differences between supported and non-supported firms

The effect of innovation promotion on innovation input (R&D- and innovation expenditures) is examined first. The probability of participation in government-funded R&D programmes (PF) is estimated using a probit model (cf. Table 1). This allows for some interesting insights into differences between Eastern and Western Germany. Using firms' patent stocks as a measure of earlier innovation

success is an essential determinant of receiving financial support. A clear indicator of a firm's access to R&D capacity or its actual engagement in R&D (an R&D department) is presented by innovation successes, which are documented via preceding patent applications. Conversely, only a small share of Eastern German firms can claim to have innovated successfully using patents; as a result, a problem concerning orientation on innovation history is posed to the promoting entity. As in the Western German states, support programmes in the "new" states have focused on the dispersal of firms' knowledge bases. This is made apparent by the fact that the existence of one's own R&D department – not recorded by the patent stock – is decisive in predicting likelihood of receiving public support, a conclusion that could also reflect the contrasting political devices affecting research and technology in the two regions. While Western Germany focuses on direct promotion of specific R&D projects, the East emphasises an indirect approach (e.g., fostering R&D personnel).

In essence, the estimation of participation likelihood in Eastern Germany resulted in a specification dependent on firm size, the R&D-department dummy, the NoPAT dummy (indicating whether a firm had never applied for a patent), firm age, export activity and firm integration. Market structure, measured as $\ln HHI$, credit rating ($\ln CR$) and size of patent stock had no influence on participation in support programmes in Eastern Germany and were thus not considered in the final estimation (see Table 1).

As expected, firm size is a significant determinant of public R&D subsidies. In addition, an existing R&D department is one of the most important determinants of support in Eastern Germany. Firms with own R&D departments demonstrate the capacity and competency to successfully carry out R&D projects.

Likelihood of participation declines in Eastern Germany as firm age increases, while in Western Germany firm age has no such influence. This effect may reflect the existence of support programmes for young high-tech firms; the application behaviour of firms can potentially change over time as well. Older firms have better funding alternatives, as external investors can more often rely on the experience of such companies than with newly founded firms. As a consequence, established companies able to provide evidence of a successful record have better access to the capital market.

Firms engaged in international competition take part in support programmes more often than other firms. This may also represent a signalling effect. Through their established position on international markets these firms have apparently proven their ability to transform innovation activities into successful products.

Table 1: Probit Regression for Programme Participation; All Firms

Dependent Variable: <i>PF</i> Exogenous variable	Eastern Germany		Western Germany	
	Coeff.	Std. error	Coeff.	Std. error
<i>lnEMP</i>	0.94***	0.174	0.05	0.106
$(\ln EMP)^2$	-0.09***	0.020	0.02**	0.010
<i>RDDEPT</i>	1.46***	0.081	/	
<i>lnPAT</i>	/		0.10***	0.022
<i>NoPat</i>	-0.37***	0.088	-0.54***	0.176
<i>LnAGE</i>	-0.18**	0.077	/	
<i>DEXP</i>	0.44***	0.076	0.55***	0.106
<i>FOREIGN</i>	-0.63***	0.166	-0.21***	0.080
<i>WGROUP</i>	-0.32***	0.098	/	
<i>lnHHI</i>	/		0.05*	0.028
<i>lnCR</i>	/		0.29***	0.105
Constants	-2.26***	0.834	-4.10***	0.693
<i>incl. industry and year dummies</i>				
Log-likelihood	-863.98		-1,533.92	
McFadden Pseudo R ²	0.337		0.165	
Number of observations	1,967		4,495	

*** (**, *) denotes significance at the of 1% (5%, 10%) level

Members of a Western German (in the case of Eastern German companies) or foreign company group receive public support less frequently. This may be due to parent companies' centralised R&D. In this case, subsidiaries do not submit applications for public innovation assistance. On the other hand, effects of entry requirements for promotion designed to be limited for subsidiaries are reflected in these variables.

Credit rating (measured by the rating CR) and market structure (*lnHHI*) also play a role in the Western German states. When one considers patent stocks in the West, R&D departments offer no additional explanatory power to the estimation of participation likelihood.

As one can deduce from Tables A1 and A2 in the appendix, a clear divergence is shown between both the Western and Eastern German states on the one hand and supported and non-supported firms on the other. Supported firms are larger on average, have an R&D department, are more likely to have applied for a patent in the past and are exporters. Particularly striking in the West are the differences in firm size: Supported companies employ an average of 652 individuals, decidedly more than non-supported firms' average of 260. As expected, the measures of innovation, R&D and innovative projects, are higher in supported firms. It does bear mentioning that the significant differences in the determinants of probability of public funding between the two groups indicate a definite selection bias. The estimated (unbounded) propensity score in particular differs sharply, amounting to 0.42 for supported firms and -0.93 for those not supported in the East. Similar deviations of -0.72 and -1.38, respectively, are also evident in Western Germany.

Impact of public R&D funds – comparing promoted firms with the control group

In order to avoid a bias due to self-selection, nearest-neighbour matching is applied in the following as described in Section 3. For the 735 (638) beneficiaries from Eastern Germany (Western Germany) the most similar firm is selected from the control group, followed by a comparison of the criteria's mean values. If no significant difference is found in the determinants of support -- particularly in propensity score -- the remaining differences in the target variable (R&D- and innovation expenditures) can be traced back to public support. The mean comparison of the exogenous variables serves here as a "quality check" of the matching procedure. If the differences disappear after the matching, the process is considered successful. However, if significant mean differences remain, the groups are not yet comparable; an additional criterion may need to be added to the matching function or further restrictions applied.

Table 2: Mean Comparison after Matching; Entire Sample

	Eastern Germany				Western Germany			
	Supported firms		Selected control group		Supported firms		Selected control group	
Number of observations	731		731		628		628	
Variable	Mean value	Std. error	Mean value	Std. error	Mean value	Std. error	Mean value	Std. error
<i>EMP</i>	157.64	11.570	144.19	6.628	634.45	33.590	584.69	29.992
<i>lnPat</i>	/		/		-6.27	0.150	-6.40	0.147
<i>NoPat</i>	0.64	0.018	0.67	0.017	0.29	0.018	0.29	0.018
<i>RDDEPT.</i>	0.68	0.017	0.64	0.018	/		/	
<i>AGE</i>	7.02	0.134	6.78	0.175	/		/	
<i>DEXP</i>	0.78	0.015	0.79	0.015	0.97	0.007	0.97	0.007
<i>WGROU</i> P	0.19	0.014	0.21	0.015	/		/	
<i>FOREIGN</i>	0.05	0.008	0.05	0.008	0.11	0.013	0.11	0.013
<i>lnHHI</i>	/		/		3.30	0.049	3.31	0.053
<i>lnCR</i>	/		/		5.27	0.011	5.28	0.011
Propensity score	0.41	0.033	0.37	0.031	-0.72	0.021	-0.73	0.021
<i>R&D</i>	0.76	0.116	0.31***	0.037	4.21	0.707	1.95***	0.196
<i>lnR&D</i>	-1.84	0.066	-5.20***	0.163	-0.35	0.077	-3.23***	0.200
<i>R&D/SALES * 100</i>	6.40	0.386	2.25***	0.191	4.38	0.244	2.22***	0.131
<i>D(R&D>0)</i>	1.00	0.000	0.67***	0.017	1.00	0.000	0.73***	0.018
<i>lnIE</i>	-1.10	0.061	-4.05***	0.169	0.25	0.072	-2.11***	0.193
<i>IE/SALES * 100</i>	10.82	0.500	5.50***	0.424	6.39	0.283	3.89***	0.197

*** (**, *) denotes a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries is identical after the matching.

In the matching, the non-supported firm with the closest propensity score is selected for each supported enterprise. In doing so, however, certain conditions must be met: The chosen twin must belong to the same industry as the promoted firm and its observation must originate from the same or immediately previous year. The possibility that twins can stem from the period *t-1* allows a firm to serve as its own control observation if its support status changes from "no" to "yes". This is a preferable case; both observations are most likely equal in non-observed criteria such as management quality.

As Table 2 demonstrates, the differences between the selected pairs disappear after the matching. However, the differences in the target variables remain significantly different from zero. Supported Eastern German (Western German) firms thus exhibit an R&D intensity of 6.4% (4.4%) on average, compared to an average of 2.25% (2.2%) in the absence of promotion. Additionally, one must consider that all of the supported firms are engaged in R&D, compared to just 67% of the control observations. According to this calculation, one-third of the beneficiary companies would not have been involved in R&D if they had not received support.

Case II: Supported Firms vs. Firms Permanently Performing R&D

If one restricts the control group to firms engaged in R&D, similar results appear in the estimation of participation likelihood. Still, in the case of Eastern Germany the export dummy continues to be insignificant. The same effects seen in the comparison of supported firms and firms in general are apparent in the remaining determinants. Overall, however, the explanatory power of the regressions with respect to participation in support programmes is noticeably diminished when comparing supported firms to firms permanently performing R&D.

Significant differences also appear before the matching (cp. appendix Tables A3 and A4). Interestingly, average firm size in the two groups is no longer dissimilar in Eastern Germany when firms active in R&D are observed.

Table 3: Probit Regression for Programme Participation; R&D-performing Firms Only

Dependent Variable: <i>PF</i> Exogenous variable	Eastern Germany		Western Germany	
	Coeff.	Std. error	Coeff.	Std. error
<i>lnEMP</i>	0.67***	0.232	-0.6	0.124
<i>(lnEMP)²</i>	-0.07***	0.026	0.03***	0.012
<i>RDDEPT</i>	0.36***	0.105	/	
<i>lnPAT</i>	/		0.08***	0.024
<i>NoPat</i>	-0.43***	0.113	-0.52***	0.195
<i>LnAGE</i>	-0.31***	0.107	/	
<i>DEXP</i>	0.14	0.108	0.28**	0.135
<i>FOREIGN</i>	-0.73***	0.188	-0.20**	0.087
<i>WGROU</i>	-0.34***	0.123	/	
<i>lnHHI</i>	/		0.05*	0.031
<i>lnCR</i>	/		0.30**	0.117
Constants	-0.24	1.124	-3.00***	0.791
<i>incl.industry and year dummies</i>				
Log-likelihood	-505.69		-1294.14	
Pseudo R ²	0.1291		0.07	
Number of observations	1,008		2,401	

*** (**, *) denotes an error probability of 1% (5%, 10%).

However, only 265 control observations (non-supported firms) are available for the 726 supported, permanent R&D performers from Eastern Germany. From one perspective this presents a problem for

the analysis; the pool of potential control observations is relatively small. This problem can be solved by making repeated allocations of individual control observations to support cases. On the other hand, this still indicates that R&D status in Eastern Germany is also susceptible to public R&D support. A considerable number of the firms not receiving support also choose not to engage in R&D. In other words, the vast majority of R&D-active companies in Eastern Germany receive some form of public promotion (cf. Figure 3). The marginal amount of control observations available in the Eastern German states is also responsible for the lack of an appropriate matching partner for approximately every eighth supported firm. The effect of the “loss” of observations may yet remain limited; R&D intensity of the non-observed firms differentiates only slightly from that of the firms included in the estimation. This results in – if anything at all – a slight underestimation of the effect of support. Sufficient control observations are available in Western Germany to prevent these problems from arising.

Table 4: Comparison of Mean Values after Matching; R&D-performing Firms Only

	Eastern Germany				Western Germany			
	Supported Firms		Selected Control Group		Supported Firms		Selected Control Group	
Number of observations	637		637		627		627	
Variable	Mean	Std. error	Mean	Std. error	Mean	Std. error	Mean	Std. error
<i>EMP</i>	135.32	7.558	149.60	7.661	629.34	32.830	592.64	30.316
<i>lnPat</i>	/		/		-6.24	0.150	-6.40	0.145
<i>NoPat</i>	0.69	0.018	0.67	0.019	9.29	0.018	0.29	0.018
<i>RDDEPT.</i>	0.66	0.019	0.66	0.019	/		/	
<i>AGE</i>	6.99	0.120	7.21	0.297	/		/	
<i>DEXP</i>	0.77	0.017	0.77	0.167	0.97	0.007	0.97	0.007
<i>WGROUP</i>	0.21	0.016	0.20	0.016	/		/	
<i>FOREIGN</i>	0.01	0.004	0.01	0.004	0.11	0.013	0.11	0.013
<i>lnHHI</i>	/		/		3.30	0.049	3.29	0.052
<i>lnCR</i>	/		/		5.27	0.011	5.28	0.011
Propensity score	0.84	0.020	0.81	0.020	-0.49	0.015	-0.50	0.015
<i>R&D</i>	0.65	0.113	0.47	0.053	4.20	0.708	1.91	*** 0.186
<i>lnR&D</i>	-1.95	0.070	-2.56	*** 0.077	-0.35	0.077	-0.35	*** 0.735
<i>R&D/SALES * 100</i>	6.24	0.416	3.13	*** 0.163	4.37	0.245	2.75	*** 0.138
<i>lnIE</i>	-1.21	0.065	-1.62	*** 0.070	0.26	0.072	-0.06	*** 0.067
<i>IE/SALES * 100</i>	10.64	0.538	6.60	*** 0.375	6.37	0.282	4.83	*** 0.221

*** (**, *) denotes a significant mean value difference in a two-sided t-test with an error probability of 1% (5%, 10%). The distribution of observations across branches is identical after the matching.

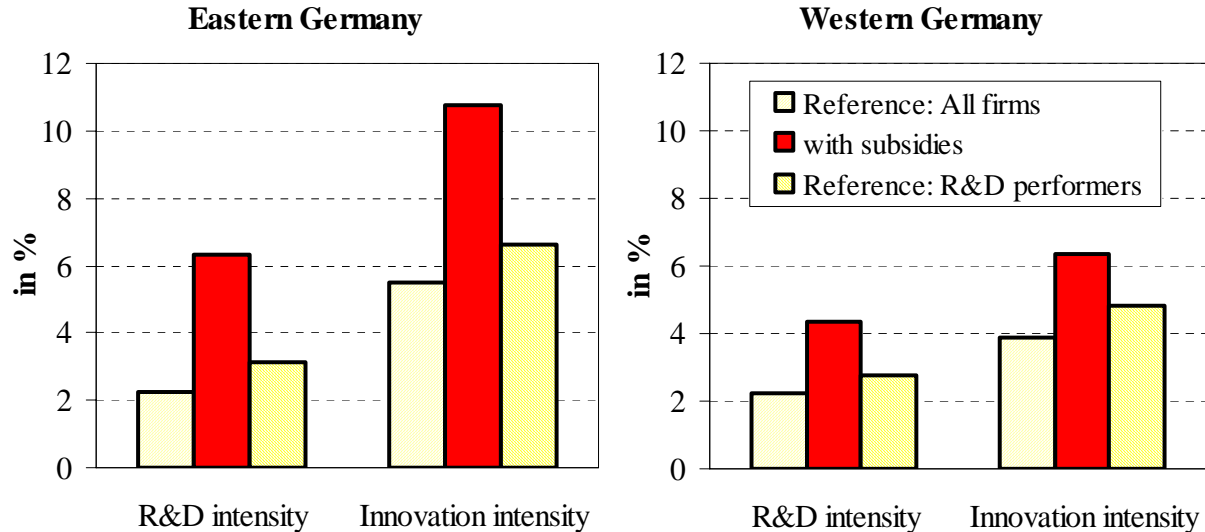
The matching results for the sample of R&D-performing firms are presented in Table 4. Promoted firms exhibit a mean value of €650,000 (€4.2 million in Western Germany). If the same firms had not received government support, they would have expended an average of just €470,000 (€1.9 million in the West). The mean of R&D expenditures is actually no longer significantly different from zero, but this can be attributed to asymmetry in the distribution of these expenditures. If this variable is transformed into logarithms or an intensity value, a t-test also produces significant differences. Alternatively, one can perform a test on median differences which is robust against skewness. This

also results in a significant difference of medians: At the median, the supported firms spent €153,000 on R&D, compared to the control group's €77,000. In the absence of government support, R&D intensity would have amounted to an average of 4.7% (2.8% in Western Germany) instead of 6.5% (4.4%); similarly, innovation intensity would have shifted from 10.6% (6.4%) to 6.6% (4.8%, cp. Table 4).

Summary of Input Additionality Effects

The results with regard to input additionality are summarized in Figure 4. Differences between the two sets of comparison groups are interpretable in that R&D promotion not only affects firms' levels of R&D expenditures: It should be recognized that such support can even stimulate the decision to initially incorporate R&D operations. The disparities indicated by Figure 4 are all statistically significant. Both R&D intensity and innovation intensity are markedly higher for supported firms compared to those not receiving funding. Additionally, one can ascertain that these differences are much more pronounced in the Eastern German states than in the West. This is traceable to both higher support levels and stronger impacts of R&D promotion in Eastern Germany. This question cannot be pursued further, however, as no information on levels of promotion is currently available in the data set.

Figure 4: Effects of Public R&D Subsidies on R&D- and Innovation Intensity



Source: Mannheim Innovation Panel; own calculations (based on Tables 2 and 4).

When restricted to R&D-performing firms, the supported Eastern German firms' mean R&D intensity weighs in at 6.5%, compared to 3.3% in the comparison group. Innovation intensity reveals similar differences, 10.6% for supported and 6.6% for non-supported firms. Of course, the fact that only 265 control observations are available for the 726 supported, R&D-active firms should be recalled. This clearly allows us to conclude that R&D status in Eastern Germany relies heavily on government funding. The bulk of the companies not receiving public R&D support are not engaged in R&D. When the comparison between firms with R&D support and those (still innovating) firms without support is

applied, the discrepancies are brought into starker relief; indeed, in this case the stimulating effect of promotion on initial implementations of R&D is also added into the model. The comparison group's R&D intensity then only amounts to approximately 2.3%. According to this estimation, only 33% of the supported firms would have been involved in research and development had they not received funding.

6. Effects of R&D Subsidies on Innovation Output

The input analyses show that R&D subsidies affect R&D spending positively in both Eastern and Western Germany. Recipient firms invest significantly more in R&D compared to the counterfactual situation where no subsidies were in place. However, it is questionable whether this additional innovation input induced by public policy also improves innovation results. It may be possible that subsidized projects are more risky undertakings than purely privately financed ones because it is more difficult to find private investors willing to support such research plans. The subsidies could also be spent inefficiently and therefore not lead to an increased output. Increases in the wages of R&D personnel without a corresponding productivity gain is an example. Finally, the subsidies could re-route a firm's R&D portfolio towards technologies through which the firm is less productive in generating innovation output.

Patent indicators are a suitable measure for an output analysis. Patent applications are closer in time to the conducted R&D projects than sales with newly developed products or cost reductions due to the implementation of new processes in production, for instance. One disadvantage is that the actual economic value of patents may be very heterogeneous. In this paper, we implicitly have to assume that the filed patents from non-subsidized firms are not more valuable than those filed by subsidized firms and vice versa. In other words, it is assumed that there is no significant correlation between the average value of a patent and the respective subsidy.

Table 5 shows the regression results of a probit model representing the propensity to patent and of a negative binomial model of patent counts for both Eastern and Western Germany.⁸ In order to test for a possible lower efficiency of publicly financed R&D expenditures, we employ the concept of knowledge production functions (cf. Griliches 1990). R&D is assumed to be the most important input for the production of patents (cf. Licht and Zoz, 1998, for estimations of knowledge production functions for Germany). Industry dummies and time dummies control for different technological opportunities and appropriability conditions. As shown in Chapter 3, we separate R&D expenditure into two components Y_i^0 and $\alpha_i = Y_i^1 - Y_i^0$, R&D expenditures which would have been spent if no subsidies were in place (Y_i^0), and in those expenditures that were induced by public funding α_i . The values of Y_i^0 and α_i are derived from the previously shown matching estimations.

⁸ Unfortunately, the data from the year 2000 cannot be used in these estimations because our patent database does not include information beyond the year 1999.

Table 5: Regressions on the patenting activity of publicly funded firms

	Eastern Germany		Western Germany	
Number of observations:	497		491	
Probit regression; dependent variable: patent application dummy				
	Coef.	Std. err.	Coef.	Std. err.
R&D induced by public funding (α_i)	0.32***	0.09	0.15***	0.03
non-subsidized R&D (Y_i^0)	0.45***	0.12	0.18***	0,03
Export intensity	0.14	0.32	0.60**	0.26
Intercept	-1.12***	0.34	-1,81***	0.53
Industry dummies; test on joint significance	$\chi^2(10) = 18.57^{**}$		$\chi^2(10) = 14.79$	
Time dummies; test on joint significance	$\chi^2(2) = 5.45^*$		$\chi^2(2) = 3.73$	
Log-likelihood	-212.03		-288.13	
Pseudo R ²	0.10		0.14	
Negative binomial regression, dependent variable: number of patent applications				
R&D induced by public funding (α_i)	0.78***	0.20	0.30***	0.04
non-subsidized R&D (Y_i^0)	0.91***	0.22	0.40***	0.04
Export intensity	-0.04	0.65	0.93**	0.39
Intercept	-1.78***	0.67	-2.13***	0.71
Industry dummies; test on joint significance	$\chi^2(10) = 17.87^*$		$\chi^2(10) = 27.03^{***}$	
Time dummies; test on joint significance	$\chi^2(2) = 4.38$		$\chi^2(2) = 16.42^{**}$	
Log-likelihood	-356.63		-853.90	
Pseudo R ²	0.07		0.09	

*** (**, *) indicate a significance level of 1% (5%, 10%).

The probit regressions on the probability of having applied for at least for one patent show that the coefficient of the non-subsidized R&D expenditures is about 0.45 in Eastern Germany and about 0.18 in Western Germany. The coefficient of publicly induced R&D is only 0.32 in Eastern Germany and 0.15 in Western Germany. Thus, the publicly funded R&D achieves a productivity amounting to about 71% ($=0.32/0.45$) of the non-subsidized R&D in Eastern Germany and about 83% ($= 0.15/0.18$) in Western Germany. Although smaller than purely privately financed R&D, the effects of subsidies are significantly positive on the output side of the innovation process. Under the assumption that firms conduct projects with the highest expected returns even without subsidies in place - and start those with lower expected returns due to the receipt of subsidies - this result is in accordance with the paradigm of decreasing marginal returns on R&D activities.

If the number of filed patent applications is considered rather than the propensity to patent, we find a similar result: The productivity of publicly funded R&D with respect to patents reaches 86% of the productivity of privately financed R&D in Eastern Germany (75% in Western Germany). The coefficient of publicly induced R&D is significantly different from zero in this case as well.

However, it should be pointed out that the difference in patent productivity between both kinds of R&D is only statistically significant in the count data model for Western Germany (at the 5% significance level). For the other cases, the hypothesis that both kinds of R&D are equally productive is not rejected.

In order to compare average patent productivity, one can calculate marginal effects based on the coefficient estimates. For instance, based on the count data model of number of patent applications, one would address the question "How does the average number of patents change if R&D activity changes?" The marginal effects of publicly induced R&D are 0.22 (0.49) in Eastern (Western) Germany. Those of privately financed R&D are 0.26 (0.64) in Eastern (Western) Germany. All values are calculated at the sample means of the corresponding R&D variable. Thus, R&D in Eastern Germany is not (yet) as productive as in Western German firms. Eastern German firms achieve roughly 41% of the Western German R&D productivity level with respect to patents in the case of non-subsidized activity (45% in case of subsidized R&D). However, this difference does not stem from the high levels of subsidies in Eastern Germany: Productivity is lower for both subsidized and non-subsidized R&D in the region.

Export intensity is entered into the patent production function for two reasons. Exporters often have a higher productivity which may also be present in the invention process. In addition, exporters may have a higher propensity to seek patent protection in order to increase their competitive position in more highly contested foreign markets. Somewhat surprisingly, we find that export activity is an important motivation for Western German firms to apply for patent protection but does not yet influence patent behaviour in Eastern Germany. One reason for this may be that Eastern German firms view even the Western German market as a "foreign" market. However, a more stringent explanation needs a more complete analysis of differences in patenting behaviour in Eastern and Western Germany (cf. Legler et al. 2004) and is left for further research.

7. Synopsis and Interpretation of Results

The preceding sections first investigate whether governmental support of innovations, particularly R&D, stimulates innovation input – measured by R&D expenditures of Eastern German firms – or if these funds merely take the place of private resources. Secondly, tests are conducted to determine whether additional, government-induced R&D expenditures have a positive effect on innovation output, which is measured by firms' patent activity. Analyses of innovation support of Western and Eastern German firms are then compared accordingly.

The econometric analyses demonstrate the presence of selection biases in receiving public R&D funds. Supported firms differ considerably from those not receiving aid: The former are larger on average, more likely to feature an R&D department, more likely to have already applied for at least one patent, and are also more likely to be internationally active. Thus, econometric methods that account for this sort of selection bias must be applied.

Estimating probability of participation in R&D support programmes shows significant discrepancies between the East and West. In Western Germany, support participation indicates a strong selection in favour of firms that already have a history of above-average amounts of innovation activity. The patent stocks of firms as a measure of past innovative success are an important determinant of

receiving financial aid. A clear signal of a firm's access to R&D capacities or engagement in R&D (i.e., an R&D department) is actually secondary to proven success in innovation. In Eastern Germany, however, only a small amount of firms are able to show a past success record in the form of patents. Government promotion is spread out across a wider basis in the East; evidence of the ability to carry out R&D is enough to be eligible for public R&D support. This finding may reflect the different policy instruments in place in both parts of Germany. While technology-specific project grants are the predominant means of R&D policy, Eastern German can also access less technology-specific R&D support and specific support for R&D labour costs.

The implementation of the econometric processes reveals positive treatment effects; that is, public funds do not substitute for firms' own resources – they stimulate innovation input. At the same time, the estimated treatment effects are more pronounced in Eastern Germany than in the West. This allows one to conclude that - compared to their Western counterparts - Eastern German firms are not as capable of acquiring capital from other financial channels. The estimations also indicate that a significant share of Eastern German firms would not be engaged in R&D without public support. This may hint at limited access to alternative sources of funding in Eastern Germany.

The aforementioned differences in the input analysis are statistically highly significant. Both R&D- and innovation intensity are considerably higher in firms receiving public R&D grants. These contrasts are also much more distinct in the Eastern states. This may be due both to the East's greater share of supported firms and a stronger stimulation effect of R&D promotion.

An analysis of firms' patent activities shows that they are affected positively by support-induced R&D in both German regions. Likelihood of having applied for at least one patent and number of patent applications are also analysed. With regard to both dimensions we find only little evidence that government-induced R&D is less productive than R&D solely financed out of firms' own pockets. Only in the case of Western Germany we do find a significant, lower productivity for publicly financed R&D. The difference in marginal productivity is less noticeable in Eastern Germany. Since Western German firms still engage in a substantial amount of R&D without government funding – allowing their average volume of R&D to be accordingly greater in comparison to Eastern German firms – the effects of promotion in Western Germany are less marked. In the East, however, publicly financed private R&D constitutes an essential component of total R&D and is thereby essential for innovation output.

In the light of the current discourse on future innovation policy in Eastern Germany, our findings shed a far more positive light on the role of R&D in the transition process than the dismal tones favoured by some contemporaries. R&D promotion has made a crucial contribution to R&D intensification in the Eastern German manufacturing industry. In the absence of public innovation promotion fewer firms would have been able to implement new products and processes in national and international markets. In this respect, there are considerable arguments for continuing such support.

On the other hand, the results also show that the findings on R&D input in the East leave something to be desired. Western German firms are able to realize a higher level of productivity with their R&D resources. Even though the differences between firms' publicly financed R&D expenditures and those privately funded are clearly greater in the West, patent productivity of supported R&D in Western Germany is still higher than firm-financed R&D in the East. However, this also implies that promotion of R&D activities in Western Germany yields higher returns in the form of patents than it does in the Eastern states. Assuming that additional R&D activity also improves international competitiveness and thus creates more export opportunities, one could consider reallocating public R&D funds from the East to the West to possibly realise a higher rate of growth, instead of using these resources to stimulate the adjustment process in Eastern Germany. Similarly, the warnings concerning the West-East transfer's growth-impairing effect cannot be fully dismissed outright. However, the overall picture more likely indicates additional public R&D instead of increasing R&D support in Western Germany at the expense of the Eastern German innovation system, which is still in transition.

References

- Almus, M. and D. Czarnitzki (2003), The Effects of Public R&D on Firm's Innovation Activities: The Case of Eastern Germany, *Journal of Business and Economic Statistics* 12(2), 226-236.
- BMBF (Hrsg.) (2003), Bericht zur technologischen Leistungsfähigkeit, Berlin. (www.technologische-leistungsaehigkeit.de).
- Bundesregierung (2004), Jahresbericht der Bundesregierung zum Stand der deutschen Einheit 2004 (available from [www.bmvmw.de/Anlage17251/ Jahresbericht-der-Bundesregierung-zum-Stand-der-Deutschen-Einheit-2003.pdf](http://www.bmvmw.de/Anlage17251/Jahresbericht-der-Bundesregierung-zum-Stand-der-Deutschen-Einheit-2003.pdf)).
- Burda, M. C., J. Hunt (2001), From Reunification to Economic Integration: Productivity and the Labour Market in Eastern Germany, *Brookings Papers on Economic Activity*, 2000-2, 1-71.
- Blundell, R. and M. Costa Dias (2000), Evaluation Methods for Non-Experimental Data, *Fiscal Studies* 21(4), 427-468.
- Blundell, R. and M. Costa Dias (2002), Alternative Approaches to Evaluation in Empirical Microeconomics, *Portuguese Economic Journal* 1(2), 91-115.
- Cohen (1995), Empirical Studies of Innovative Activity, in: P. Stonemann (Hrsg.), *Handbook of the Economics of Innovation and Technological Change*, Oxford/Cambridge (MA), 182-264.
- Czarnitzki, D. (2001), Die Auswirkungen der Forschungs- und Technologiepolitik auf die Innovationsaktivitäten ostdeutscher Unternehmen, *Schmollers Jahrbuch* 121(4), 539-560.
- Czarnitzki, D. (2002), Research and Development: Financial Constraints and the Role of Public Funding for Small and Medium-Sized Enterprises, ZEW Discussion Paper No. 02-74, Mannheim.
- Czarnitzki, D. (2005), The Extent and Evolution of the Productivity Deficiency in Eastern Germany, forthcoming in the *Journal of Productivity Analysis*.
- Czarnitzki, D. and K. Kraft (2004), Innovation indicators and corporate credit ratings: evidence from German firms, *Economics Letters* 82(3), 377-384.
- David, P.A., B.H. Hall, and A.A. Toole (2000), Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence, *Research Policy* 29, 497-529.
- DIW/IAB/IfW/IWH/ZEW (2003), Zweiter Fortschrittsbericht wirtschaftswissenschaftlicher Institute über die wirtschaftliche Entwicklung in Ostdeutschland, Halle.
- Dohnani, K. v. (2004) The Reconstruction of the East and Policies of Reform Form a Unit, *ifo Schnelldienst* 10/2004, 28.5.2004.
- Eurostat and OECD (1997), *Proposed Guidelines for Collecting and Interpreting Technological Innovation Data*, Paris.
- Geroski, P.A., J. van Reenen and C.F. Walters (1993), Innovations, Patents and Cash Flow, CEPR Discussion Paper 1432, London.
- Griliches, Z. (1990), Patent Statistics As Economic Indicators, *Journal of Economic Literature* 92, 630-653.
- Griliches, Z. and J. Mairesse (1984), Productivity and R&D at the firm level, in: Z. Griliches (Hrsg.), *R&D, patents, and productivity*, Chicago and London: University of Chicago Press, 339-374.
- Hall, B.H. (1990), The manufacturing sector master file: 1959-1987, NBER Working Paper Series No. 3366, Cambridge, MA.
- Hall, B.H. (2000), Innovation and market value, in: R. Barrell, G. Mason and M. O'Mahony (Hrsg.), *Productivity, Innovation, and Economic Performance*, Cambridge.

- Hall, B.H. (2002), The financing of research and development, *Oxford Review of Economic Policy* 18(1), 35-51.
- Hall, B.H., A. Jaffee, and M. Trajtenberg (2005), Market Value and Patent Citations, forthcoming in the *Rand Journal of Economics*.
- Heckman, J.J., R.J. LaLonde and J.A. Smith (1999), The Economics and Econometrics of Active Labor Market Programs, in: O. Ashenfelter and D. Card (Hrsg.), *Handbook of Labor Economics* 3.
- Holemans, B. and L. Sleuwaegen (1988), Innovation Expenditures and the Role of Government in Belgium, *Research Policy* 17, 375-379.
- Janssens, W. and S. Suetens (2001), Are R&D Subsidies in the Flemish Region Useful? A Qualitative Study, Discussion Paper 07, CESIT, University of Antwerp.
- Janz, N., G. Ebling, S. Gottschalk and H. Niggemann (2001), The Mannheim Innovation Panels (MIP and MIP-S) of the Centre for European Economic Research (ZEW), *Schmollers Jahrbuch - Zeitschrift für Wirtschafts- und Sozialwissenschaften* 121, 123-129.
- Klette, T.J., J. Moen and Z. Griliches (2000), Do Subsidies to Commercial R&D Reduce Market Failures? Microeconomic Evaluation Studies, *Research Policy* 29, 471-495.
- Legler, H., B. Gehrke, U. Schasse, C. Rammer and U. Schmoch (2004), Innovationsindikatoren zur technologischen Leistungsfähigkeit der östlichen Bundesländer, Studien zum deutschen Innovationssystem No. 20-2004, www.technologische-leistungsfaeigkeit.de.
- Leydesdorff, L. and M. Fritsch (2005), Measuring the Knowledge Base of Regional Innovation Systems in Germany in terms of a Triple Helix dynamics, Paper to be presented at the Fifth International Triple Helix Conference in Turn, 18-21 May 2005.
- Licht, G. and K. Zoz (1998), Patents and R&D - An Econometric Investigation Using Applications for German, European and US Patents by German Companies, *Annales d'Économie et de Statistique*, 329-360.
- Meske, W. (2000), Changes in the Innovation System in Economies in Transition: Basic Patterns, Sectoral and National Particularities, *Science and Public Policy* 27, 253-264.
- OECD, Eurostat (1997), Proposed Standard Practice for Collecting and Interpreting Technological Innovation Data – Oslo Manual, Paris.
- Porter, M.E. (1998), *On Competition*, Cambridge, Mass.
- Rosenbaum, P. R. and D. B. Rubin (1983), The Central Role of the Propensity Score in Observational Studies for Causal Effects, *Biometrika* 70, 41-55.
- Rubin, D.B. (1977), Assignment to Treatment Group on the Basis of a Covariate, *Journal of Educational Statistics* 2, 1-26.
- Seitz, H. (2004), The Future Structure of the Reconstruction of East Germany, *ifo schnelldienst* 10/2004, 28.5.2004.
- Toivanen, O. and P. Niininen (2000), Investment, R&D, Subsidies and Credit Constraints, Helsinki.

Appendix

Table A1: Mean Value Comparison before Matching – Eastern Germany, Entire Sample

	Supported firms		Potential control group	
Number of observations	735		1224	
Variable	Mean	Std. error	Mean	Std. error
<i>EMP</i>	157,62	11,510	94,97***	5,714
<i>NoPat</i>	0,64	0,018	0,86***	0,010
<i>RDDEPT</i>	0,68	0,017	0,15***	0,010
<i>AGE</i>	7,02	0,134	10,05***	0,421
<i>DEXP</i>	0,79	0,015	0,46***	0,014
<i>WGROUP</i>	0,19	0,014	0,17	0,011
<i>FOREIGN</i>	0,05	0,008	0,04	0,006
Propensity score	0,42	0,033	-0,93***	0,022
<i>R&D</i>	0,76	0,116	0,08***	0,017
<i>lnR&D</i>	-1,83	0,066	-9,31***	0,100
<i>R&D / SALES * 100</i>	6,42	0,385	0,56***	0,696
<i>D(R&D>0)</i>	1,00	0,000	0,22***	0,012
<i>lnIE</i>	-1,10	0,613	-8,26***	0,128
<i>IE / SALES * 100</i>	10,85	0,500	2,53***	0,246

*** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.

Tabelle A2: Mean Value Comparison before Matching – Western Germany, Entire Sample

	Supported firms		Potential control group	
Number of observations	638		3.856	
Variable	Mean	Std. error	Mean	Std. error
<i>EMP</i>	652.11	34.067	259.95***	7.671
<i>lnPAT</i>	-6.26	0.148	-8.97***	0.060
<i>NoPat</i>	0.29	0.018	0.62***	0.008
<i>DEXP</i>	0.97	0.007	0.79***	0.007
<i>FOREIGN</i>	0.12	0.013	0.10*	0.005
<i>lnHHI</i>	3.31	0.049	3.00***	0.019
<i>lnCR</i>	5.28	0.011	5.31***	0.004
Propensity score	-0.72	0.021	-1.38***	0.010
<i>R&D</i>	4.29	0.701	0.54***	0.040
<i>lnR&D</i>	-0.33	0.076	-6.68***	0.080
<i>R&D / SALES * 100</i>	4.35	0.241	1.11***	0.042
<i>D(R&D>0)</i>	1.00	0.000	0.46***	0.008
<i>lnIE</i>	0.28	0.072	-5.41***	0.086
<i>IE / SALES * 100</i>	6.38	0.280	2.60***	0.083

*** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.

Table A3: Mean Value Comparison before Matching – Eastern Germany (R&D-performers)

	Supported firms		Potential control group	
Number of observations	726		265	
Variable	Mean	Std. error	Mean	Std. error
<i>EMP</i>	143.61	7.741	146.61	14.175
<i>NoPat</i>	0.64	0.018	0.81***	0.024
<i>RDDEPT</i>	0.68	0.017	0.50***	0.031
<i>AGE</i>	7.04	0.135	9.74**	0.886
<i>DEXP</i>	0.78	0.015	0.68**	0.029
<i>WGROU</i>	0.19	0.015	0.22	0.026
<i>FOREIGN</i>	0.05	0.008	0.09**	0.018
Propensity score	0.85	0.019	0.37***	0.033
<i>R&D</i>	0.65	0.100	0.37**	0.076
<i>LnR&D</i>	-1.87	0.065	-2.87***	0.122
<i>R&D / SALES * 100</i>	6.35	0.388	2.60***	0.289
<i>lnIE</i>	-1.13	0.060	-1.75***	0.120
<i>IE / SALES * 100</i>	10.76	0.504	6.42***	0.582

*** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.

Table A4: Mean Value Comparison before Matching – Western Germany (R&D-performers)

	Supported firms		Potential control group	
Number of observations	637		1,762	
Variable	Mean	Std. error	Mean	Std. error
<i>EMP</i>	645.44	33.460	376.83***	13.459
<i>lnPAT</i>	-6.26	0.148	-7.44***	0.093
<i>NoPAT</i>	0.29	0.018	0.42***	0.012
<i>DEXP</i>	0.97	0.007	0.91***	0.007
<i>FOREIGN</i>	0.12	0.013	0.13	0.008
<i>lnHHI</i>	3.31	0.049	3.08***	0.030
<i>lnCR</i>	5.28	0.011	5.27***	0.006
Propensity score	-0.49	0.016	-0.74***	0.009
<i>R&D</i>	4.28	0.702	1.18***	0.085
<i>lnR&D</i>	-0.33	0.076	-1.45***	0.045
<i>R&D / SALES * 100</i>	4.35	0.241	2.44***	0.081
<i>lnIE</i>	0.27	0.072	-0.62***	0.042
<i>IE / SALES * 100</i>	6.39	0.280	4.61***	0.143

*** (**, *) denote a significant mean difference in a two-sided t-test at the level of 1% (5%, 10%). The distribution of observations across industries varies before the matching.